ON THE VARIATION IN THE VALUE OF THE ATMOSPHERIC ELECTRICAL POTENTIAL WITH THE ALTITUDE.

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Observations taken during the past two years have convinced the writer that some sort of relation should exist between the value of the potential gradient due to the charge existing in the air and the altitude of the place of observation, and some account of this matter has already been published by him. With the object of obtaining further information, a journey was made in September last from Bloemfontein to Lourenço Marques via Johannesburg, and then from Johannesburg to Durban. In this way places of observation could be secured where the altitude varied from sea-level up to nearly 7,000 feet, and records were taken of the potential gradient at as many places as possible.

The apparatus used consisted of a "Wilson" pattern gold-leaf electrometer, furnished with a collecting-plate of brass coated with a radium preparation. This latter had been in use for some time and gave consistent results, but ionium would probably be a better material than radium to work with. The results may, however, be regarded as comparative rather than absolute, and tests of the efficiency of the plate at the beginning and end of the observations showed that it had not changed in its power of taking the potential of that layer of the atmosphere in which it happened to be. The electroscope was calibrated by a number of small storage cells used in conjunction with a sliding condenser, allowing potentials up to 500 volts to be measured. The electroscope was usually arranged so that the collecting plate was 140 cm. above the ground, but in some cases where the potential was high a less height was used. The movements of the gold leaf were observed by a reading microscope with a scale in the eyepiece. The gold leaf rapidly took up a fixed position (in a uniform field) and the double case of the instrument effectually eliminated any disturbance by the wind.

The start was made from Bloemfontein on September 24th. Between that place and Vereeniging there is not much change in level, and previous observations have shown that the potential gradient is fairly uniform. From Vereeniging to Johannesburg there is a rise of 1,000 feet, and this is accompanied by a decided fall in the potential gradient until Germistom is reached, and there, considerable fluctuations are noticed, especially if a strong wind is blowing. In Johannesburg the changes in the value of the gradient are so remarkable that they will be treated separately, and the general results from Johannesburg to Lourenço Marques and from Johannesburg to Durban taken first.

Johannesburg to Lourenço Marques.

After Johannesburg the first halt was made at Belfast, and here a day's observations were taken from 5.40 a.m. to 9.30 p.m. The country round Belfast is very open and free from trees, so that there were no circumstances to disturb the normal potential. The sky was practically free from cloud all day and the potential gradient appeared to follow the normal course, save that the second maximum occurred at 5 p.m. instead of about 8 to 9 p.m. By "normal" course is meant that the potential rises after sunrise up to a maximum value about 8 p.m., then falls to a minimum and remains constant for several hours, then rises to a second maximum which is lower than the first, and then falls to another minimum, until just before sunrise on the following day.

Table I. shows the values of the potential gradient in volts per metre at various times during the day.

Table I.

Belfast, 6,500 *feet.*

Time.	Pot. Grad.	Time.	Pot. Grad.	Time.	Pot. Grad.	Time.	Pot. Grad.
5.40 a.m.	30	8.30	48	1.15	20	5.45	50
5.50	36	9.0	48	1.30	20	6.0	48
6.0	40	9.30	46	2.0	25	6.10	30
6.5	42	10.0	46	2.30	33	6.20	27
6.10	46	10.35	43	2.35	36	7.0	23
6.20	48	11.0	40	2.50	40	7.15	18
6.30	50	11.30	35	3.0	42	7.30	25
6.47	54	11·45	28	3.25	45	7.45	25
7.0	56	12.0	22	3.45	45	8.0	28
7.15	58	12.15 p.m.	18	4.0	50	8.30	28
7.30	58	12.20	20	4.40	60	8.45	26
7.35	58	12.30	20	4.50	70	9.0	20
7.50	56	12.45	20	5.0	80	9.15	20
8·0	48	1.0	20	5.25	57	9.30	20

On the following day observations from 5.10 a.m. to 7.30 p.m. gave practically the same readings as those recorded in the Table.

From Belfast to Lourenço Marques observations were taken as opportunity offered during the stoppage of the train, but unless a clear space some distance to windward from the engine could be found the results were valueless. It has been shown in previous papers* how the steam from an engine affects the potential gradient.

The best values are those given in Table II., which were observed during long stoppages of the train.

TABLE II.

Belfast to Lourenço Marques.

	Time.	Altitude.	Pot. Grad.
Belfast	7.30 a.m.	6,500	58
Machadodorp	8.5	5,279	90
Waterval Boden	8.30	4,826	100
Waterval Onder	9.0	4,144	110
Sycamore	9.20	3,841	140
Elandshoek	10.29	2,930	150
Cairn	11.0	2,410	180
Nelspruit	11.40	2,349	200
Crocodile Poort	12.20 p.m.	1,827	210
Kapmuiden	12.50	1,342	250
Koomati Poort	2.50	619	300
Lourenço Marques	4.35	0	500

A progressive increase in the potential gradient is seen as the altitude diminishes. The numbers given are not those actually observed, but numbers calculated as follows:—

In order to compare the potential gradient at one place with that at another, the times of observation should be the same, or rather corresponding points on the daily curve should be taken. This, of course, would have necessitated a stop of one day at each place, and as this was impossible the following method was used, which, although obviously inaccurate, will not be very far from the truth. The relation between the maximum value of the potential gradient and the minimum value, is, for Bloemfontein as 4 : 1, for Pretoria 4 : 1, Belfast 4·5 : 1, Lourenço Marques 5 : 1 for the morning observation, and rather less for the afternoon. As an approximation the minimum may be taken as occurring at

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12 noon. The Table attempts to show what the maximum value would be at the place of observation. Straight lines were drawn upon squared paper from the value of the gradient at its maximum to that of the value at its minimum, the horizontal line being the axis of time, and then assuming that the potential falls with the time, values of the maximum gradient can be found by extrapolation. For example, an observation at Crocodile Poort at 11 a.m. gave a gradient of 110 volts per metre, but by extrapolation it is assumed that the maximum value of the potential gradient would be 210. Proceeding in this fashion, the values given in the Table have been deduced, but they must be taken as approximate only. The values of Belfast and Lourenço Marques are of course definite.

At Lourenço Marques two and a half days' observations were taken, partly at the Observatory, on the beach, and at points in the neighbourhood. The humidity of the air was very great, which interfered with the first half-day's and also the next day's work, but the third day, after 9 a.m., was drier, and gave what may be regarded as a normal set of observations.

A day's results, taken at the Observatory, are given in Table III.

TABLE III.

Lourenço Marques, September 27th.

Time.	Pot. Grad.	Time.	Pot. Grad.	Time.	Pot. Grad.
5.30 a.m.	60	9.40	174	5.40	100
5.40	60	9.45	174	6.10	100
5.50	60	10.0	162	6.30	120
5.57	68	10.15	125	7.0	176
6.0	68	10.30	118	7.15	180
6.10	68	10.40	108	7.30	180
6.20	80	11.0	108	7.45	180
6.30	75	11.10	95	8.0	165
6.35	100	11.30	95	8.15	160
6.40	104	11.55	95	8.30	150
6.50	162	12.0	95	8.45	110
7.5	260	12.30 p.m.	95	9.0	100
7.17	280	↓		9.15	87
7.35	280			9.30	87
7.40	158			9.45	90
7.50	225				
8.0	200				
8.10	280				
8.20	260				
8.30	196	5·25	100		

The course followed by the potential gradient is thus of the normal kind, but the value of the maximum is much less than the previous half-day's work would have led one to expect. The atmosphere was steamy and probably interfered with the efficiency of the radium collecting-plate. From 12.30 p.m. to 5.30 p.m. the gradient was practically constant.

On the following morning there was a "Scotch" mist, which made observations valueless until 8.30 a.m., when the mist cleared away and for the rest of the day the indications were normal. Considerable wind in gusts was blowing up to 8.30, and dust might have been caught up, thus diminishing the positive charge in the air.

TABLE IV.

Lourenço Marques, September 28th.

Time.	Pot. Grad.	Time.	Pot. Grad.	Time.	Pot. Grad.
5.50 a.m.	30	6.40	30	7.45	30
6.0	0	6.50	30	8.0	0
6.5	35	7.0	45	8.30	60
6.10	30	7.15	48	8.45	100
6.12	0	7.30	110		
6.15	60	7.35	62		
6.20	80	7.40	60		
6.30	30				
After mist had cleared away					
9.30	400	11.0	310	12.0	250
9.45	382	11.5	330	12.15 p.m.	205
10.0	360	11.15	335	12.30	260
10.15	310	11.30	300	12.45	250
10.30	310	11.40	300		
10.45	320	11.50	250		

JOHANNESBURG TO DURBAN.

On the down journey observations could not be taken on account of rain until Pietermaritzburg was reached, and then between 6 p.m. and 10 p.m. a maximum potential gradient of about 200 volts per metre was obtained, but as rain was falling in the neighbourhood the observation was not of much value.

Next day observations taken on a clear open space at the south end of the town gave the results shown in Table V.

TABLE V.

Pietermaritzburg, October 1st.

Time.	Pot. Grad.	Time.	Pot. Grad.	Time.	Pot. Grad.
5.30	100	6.10	140	7.0	160
5.40	114	6.20	120	7.15	188
5.50	108	6.30	120	7.30	205
5.55	120	6.40	135	7.45	230
6.0	135	6.50	140	8.0	260

Pietermaritzburg is 2,200 feet above the sea-level and lies in a hollow, the hills rising to over 5,000 feet. From Pietermaritzburg a journey was made to Howick, 3,440 feet above sea-level. This was reached at 10 a.m. At Howick there is a waterfall on the Umgeni River, which drops sheer down for 360 feet, and gives rise to a considerable cloud of spray, and this, as anticipated, from comparison with the Victoria Falls, was the seat of a large amount of negative electrification. The fall is about 2½ miles from the railway station, and observations were taken as nearly as possible along the straight line joining the station and the fall. At about 2 miles from the fall the gradient was 200 volts per metre, and steadily diminished as the fall was approached. The electrification was of course positive in sign. At 350 yards from the fall the electrification was *zero*, and on getting nearer the fall the potential rose rapidly, reaching a very high *negative* value, probably 2,000 volts per metre, at the edge of the chasm. The shape of the gorge enables one to take observations for more than half of a circle round the fall as a centre, and also at Stockdale on the side opposite to the fall.

During the observation a distant thunderstorm was raging, and when the electroscope was on the zero line each flash was accompanied by a sudden rise in the potential to + 60 volts, but on a little rain falling the potential rose to a higher negative value.

Between Pietermaritzburg and Durban observations were prevented by rain. At Durban the potential was very high even during the afternoon, and at 7 p.m. reached the value of about 350 volts per mile on the beach, and close to the dock over 400; the high value at the latter place being due to the clouds of steam emitted by several vessels in the port.

The following morning a rapid journey was made from Umbilo to Umgeni via Durban, between the hours of 7.30 and 8 a.m. These places are at practically sea-level, but are a little way inland, and the object was to ascertain whether the potential gradient was constant over a distance of above 8 miles. The potential varied from 400 to 500 volts per metre, and, making allowance for trees, was practically constant. Observations were taken on the beach facing the Indian Ocean. A strong wind was blowing at the time, and considerable fluctuations were noticed and found to be due to the sand blown by the wind. Standing in the water the positive potential gradient was about 500 volts per metre, but this fell on walking in the direction the wind was blowing to 140, and rose again on passing beyond the range of the blown sand.

The maximum value of the potential gradient was 500 volts per metre, and the minimum a little under 300. The range is thus smaller than usually found, but this may have been due to the mist, which was present most of the day.

On the return journey to Johannesburg observations were taken at the places given in Table VI.; the values of the potential gradients are those actually observed. At times mist was present. The values are of quite a different order from those recorded for Durban, Pietermaritzburg, or Lourenço Marques.

Observations taken between Pietermaritzburg and Johannesburg give the following :—

TABLE VI.

October 4th.

	Altitude.	Time.	Pot. Grad.
Glencoe	4,320	6.0 a.m.	60
Dannhause	4,429	—	55
Newcastle	3,893	7.30 ,,	90
Boscobello	4,414	8.35 ,,	60
Inkwilo	4,554	8.50 ,,	48
Mount Prospect	4,983	9.10 ,,	45
Majuba	5,225	9.30 ,,	45
Charles Town	5,386	—	40
Volksrust	5,429	10.0 ,,	45
Zand Spruit	5,413	10.29 ,,	37
Paardekop	5,652	11.10 ,,	35
Standerton	5,022	12.40 p.m.	50
Val	5,160	1.50 ,,	50
Balfour	5,275	3.0 ,,	40
Heidelburg	5,026	4.0 ,,	40
Nigel	5,041	4.20 ,,	40

These values do not indicate much, and owing to the different times at which they were taken the results are not comparable, but they show a very marked difference from those taken at sea-level and at Maritzburg.

OBSERVATIONS AT JOHANNESBURG.

In July, 1911, some casual observations were taken of the potential gradients at Johannesburg and the value found to be much higher than that at Pretoria and Vereeniging, places about 45 miles from Johannesburg, and at a lower altitude, and also some considerable variations were observed in the values at different points outside the town. Very large quantities of steam and smoke are emitted from the engines at the mines, and these must have some influence upon the potential of the air in the neighbourhood. Another factor which has to be taken into account is the cloud of fine dust which rises from the mine heap during the process of "tipping" and also caught up by the wind. Steam gives to air a positive charge, whilst dust gives a negative.

Observations were begun at the Observatory on September 25th at 5 a.m. and continued until a steady value appeared to be reached, and the results are given in Table VII.

TABLE VII.

Johannesburg, September 25th.

Time.	Pot. Grad.	Time.	Pot. Grad.	Time.	Pot. Grad.
5.0 a.m.	60	6·25 a.m.	100	7.55 a.m.	160
5.10	66	6.30	100	8.0	180
5.12	70	6.40	105	8.20	150
5.30	75	6.50	115	8.30	100
5.45	80	7.0	125	8.40	155
6.0	80	7.10	150	9.0	155
6.10	98	7.15	160	9.20	160
6.17	95	7.20	168	9.30	160
6.20	95	7.30	168	9.45	180
				10.0	168
				10.20	168
				↓	
				11.40	160

It may be seen that the variation is not so great as that observed in the open country or in such places as Bloemfontein or Lourenço Marques.

At 10.20 a journey was made to Norwood, about 3 miles to the north of the Observatory, and the gradient taken there. Its value was only *52*, and on returning to the Observatory the value there was 160, and kept at this for half an hour. The wind was blowing strongly from Norwood to Johannesburg.

From the Observatory to the centre of the town the gradient diminished, reaching a zero value in Joubert Park. On the roof of the School of Mines it was + 85 at 1 p.m., but, as this place is near to the railway station, every passing train caused the value to change rapidly.

Passing to the south side of the town, an open space is reached just before the Village Deep Mine, and observations taken in this neighbourhood showed surprising changes in the magnitude and sign of the electrification. A strong wind was blowing from the north at the time, and standing to the north of the mine the potential gradient was about +40. From the mine heap at the south end of the mine a large cloud of dust was being blown, and taking an observation at this end the magnitude of the potential gradient was *300* to *400* and *negative*. This abnormal electrification persisted for a considerable distance and was more than 150 volts per metre at a mile and a half away and still negative.

Inside the mine enclosure the electrification was positive close to the engines, zero in some places, negative at the beginning of the mine heap, the magnitude of the negative charge increasing as the heap was ascended. The same thing was seen near to other mines.

At the School of Mines the potential gradient was +120 at 4.30 and at the Observatory +160 at 6.30.

The general electrical conditions about Johannesburg are thus very abnormal as compared with other places in South Africa, and the cause is clearly due to the steam and dust.

On returning from Lourenço Marques on September 30th, the observations were repeated, but with very different results. There was no tipping of the sand going on, and very little wind, with the consequence that the electrification was everywhere *positive*, and also of high value. At the School of Mines the value was +200 at 10 a.m., and +250 at the Observatory at 4 p.m. On returning from Durban on October 5th the conditions were the same as on September 24th, viz., positive to the north, negative to the south of the town, with very high value near to the mine heap, from which clouds of dust were rising. The general results of the Johannesburg observations show to what a great extent the potential gradient in the atmosphere is influenced by steam and dust, and also that the influence is a local one. The various factors which influence the electrification of the atmosphere have been considered in a communication made to the *South African Journal of Science*.* An extended series of observations on the electrification caused by raising clouds of dust is now in progress, and will be published shortly.

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SUMMARY.

1. The potential gradient due to the normal electrification of the atmosphere varies inversely with the altitude, but the observations taken do not show any proportionality.

2. The daily variation in the value of the gradient follows the same course in places at high or low altitudes, save in the case of Johannesburg.

3. The variations at Johannesburg are due to the presence of steam and dust from the mines.